Scientific Reports on Resource Issues 2013 Volume 1 Part 1

International University of Resources (IUR) Pages 309-315

A System Dynamics Model of Mining Cost Estimation

P. Sontamino[1], C. Drebenstedt[2]

ABSTRACT: A System Dynamics Model of Mining Cost Estimation (DMMCE) is developed for analyzing cost in mining by using the open pit mining cost estimation theory. Generally, the mining cost estimation theory is separated into 3 groups including, (1) Capital Cost, (2) Operating Cost, and (3) G&A Cost (General and Administrative Cost). Moreover, today the environmental problem of mine is a more serious issue, but the function of Environmental Cost was not clearly included in mining cost estimation theory. Thus, in DMMCE, the generic structure of environmental protection cost of mining was added to the model structure, and it will be extended more details in the further development.

A development of the model was transferred the parameters and equations of the mining cost estimation theory to be a system dynamics model by using Vensim DSS Software. After that, the DMMCE was used to simulate many scenarios for understanding the behavior of cost estimation when increasing mining production rate. Moreover, The using the sensitivity analysis function of the software to calculate probability of the range condition results can make more understanding of overall mining cost while changes production planning rate and the unit environmental protection costs.

Therefore, the DMMCE is a prototype dynamics model of mining cost estimation. It is an alternative tool, that fast and flexible to calculate the overall mining cost which included the structure of environmental protection cost of mining. It is a new and beginning modification of mining cost estimation which including functions of environmental protection cost. However, it will need to be developed the detail function of environmental protection cost of mining in the future.

Key words: System Dynamics Model, Mining Cost Estimation

1. Introduction

How much does it cost of the mining project, it is one of the targets that mining company wants to know before deciding to invest in mining project. So, one of the first steps in decision making on investment in mining, the mining company have to estimate total cost of the mining project.

In the past, mining cost estimation focus on the costs for making production, but nowadays the environmental problem of mining is a serious issue of social community. The environmental protection cost becomes a very important point for a mining company that cannot be rejected.

In the cost theory, the arrangement groups of costs have been many ways such as

[1] M. Sc. Phongpat Sontamino, Faculty of Engineering, Prince of Songkla University, Thailand, phongpat.s@psu.ac.th
[2] Prof. Dr. Carsten Drebenstedt, Institut für Bergbau und Spezialtiefbau, TU Bergakademie Freiberg, Germany, drebenst@mabb.tu-freiberg.de

Direct Cost and Indirect Cost, or Capital Cost (Investment Cost), Operating Cost, and General and Administrative (G&A) Cost, etc. Generally, the ways to estimate the mining cost are used a calculator, or spreadsheet software as, MS Excel. However, the calculator needs so much time to calculate, and also a MS Excel is not flexible to change multiple variables for simulating scenarios.

Therefore, the new way to calculate and estimate cost of mining by using the system dynamics model is proposed. It is a flexible alternative tool to calculate and make the scenario of mining cost estimation.

2. Objective

To develop a system dynamics model of mining cost estimation. It can help to simulate an overall mining cost, and also further be a part of decision making tool of mine planning by using system dynamics model.

3. Literature Reviews

3.1 The System Dynamics Theory and Application

System Dynamics (SD) which founded by Prof. J.W. Forrester in 1950 [2], is a theory of system structure and a set of tools for representing the structure of complex systems and analyzing their dynamic behavior. It has many commercial software help to create an SD model but Vensim software [3] is one of the most popular software used to develop the SD model. Moreover, it also has a free version for the user. In Fig 1 shows the generic structure of an SD model created by using Vensim Software.

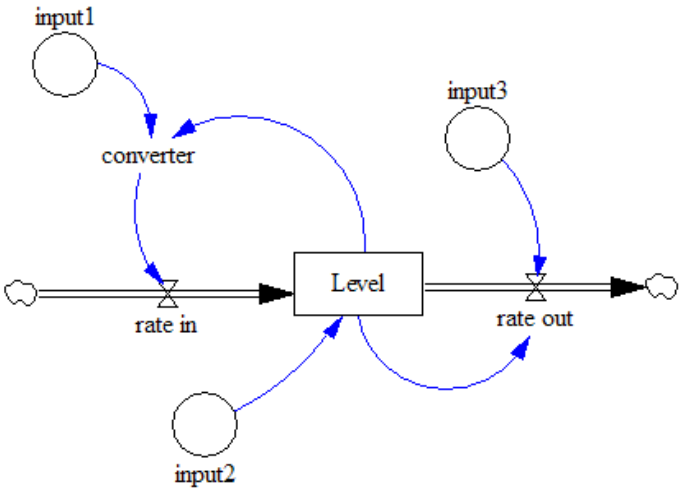

Figure 1: Simple SD Model structure

3.2 The Mining Cost Estimation Theory

In this paper, mining cost estimation is separated cost into 3 groups. Firstly, Capital Cost, Secondly, Operating Cost, and finally, General and Administrative Cost [1]. In Fig. 2 shows a detail list of mining cost structure group.

Figure 2: The list of mining cost estimation structure

The general equation of mining cost estimation is shown below [4].

$$Y=k*X^n \quad \text{——————} \quad (1)$$

When Y is cost estimation

X is a variable to be a causal of Y

k is a unit cost related to X

n is a power to control a changing trend of the curve

4. Research Methodology

This paper developed a system dynamics model of Mining Cost Estimation and also adding the input function of environmental cost into the model. The model was developed using Vensim DSS software. Moreover, the background of mining cost estimation function and value, mostly from chapter 2 of the book "Open Pit Mine Planning and Design" by Hustrulid, W.A. and M. Kuchta [1], and additional information from the SME mining engineering handbook [4].

4.1 Basic Flow Diagram of the Model

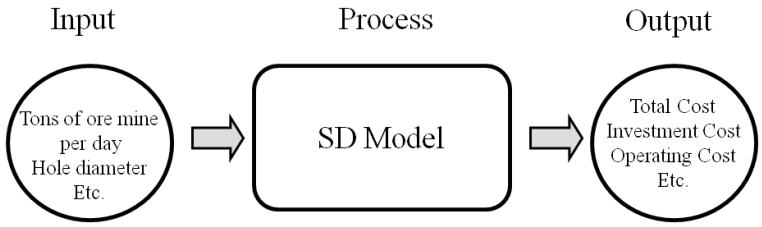

Figure 3: Basic diagram of the mining cost estimation model

4.2 Scenario simulation

The example scenario condition is calculated the condition of surface coal (lignite) mining cost estimation. In case of lignite reserves in south of Thailand is around 323,000,000 tons, assume the production planning rate is around 17 million tons/year, and the price of lignite around 17 dollars/ton. The working day is 300 days/year, and the average stripping ratio around 10 tons of waste per tons of ore.

A scenario simulation was calculated by changing the mining production planning from 5,000 tons/day to 60,000 tons/day.

4.3 Sensitivity analysis conditions

There are 2 cases of sensitivity simulations condition, the first case is a condition of none adding environmental protection cost function (CE_sens-b). The second case is an added function of environmental protection cost (CE_sens).

In the sensitivity simulation condition, the groups of input variable were change following Table 1 below.

Table 1: Sensitivity analysis conditions

CE_sens-b	CE_sens
1. Stripping ratio=RANDOM_UNIFORM (5,15)	1. Stripping ratio=RANDOM_UNIFORM (5,15) 2. n. CEnvi=RANDOM_UNIFORM (0.9,1.1) 3. n. OEnvi=RANDOM_UNIFORM (0.9,1.1) 4. n. GEnvi=RANDOM_UNIFORM (0.9,1.1) 5. k. CEnvi=RANDOM_UNIFORM (0,1) 6. k. OEnvi=RANDOM_UNIFORM (0,1) 7. k. GEnvi=RANDOM_UNIFORM (0,1)

5. Results

5.1 Model Structure

The main causal tree structure of DMMCE is shown in Figure 2.

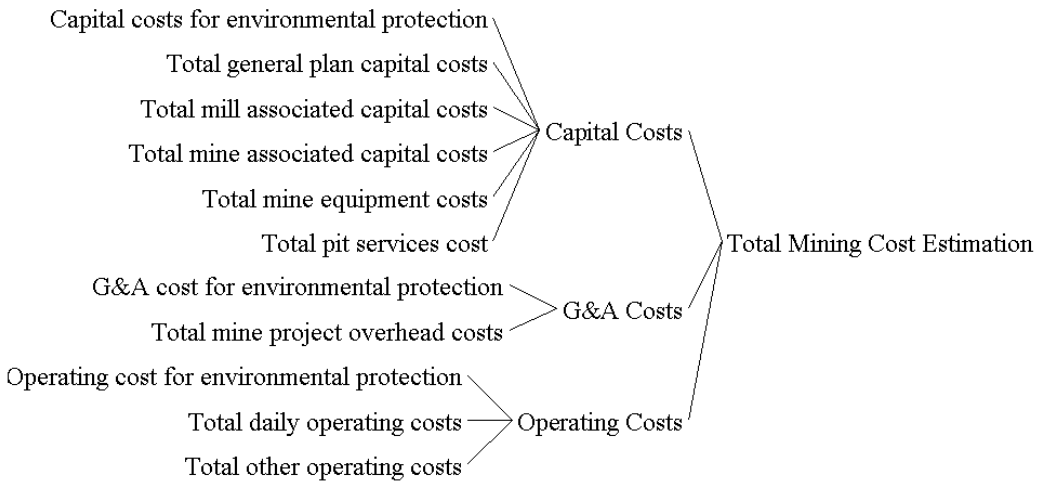

Figure 4: The main causal tree structure of DMMCE

In the causal tree diagram (Fig. 4), the cost for environmental protection variables were added separately into 3 groups of mining cost estimation, (1) Capital cost for environmental protection, (2) G&A cost for environmental protection, and (3) Operating cost for environmental protection.

5.2 Simulation Results

The DMMCE can show the calculation result when changed the values of input variables. In the case of the example simulation condition, total cost of mining increases

(from 65 million dollars to 353 million dollars) when mining production planning increase (from 5,000 tons/day to 60,000 tons/day), and the operating cost per production is decreasing (from 15.6 dollars/ton to 7.7 dollars/ton). Moreover, at mining production planning rate 57,250 tons/day (around 17 million tons/year), the total mining cost estimation is around 342 million dollars and operating cost around 7.8 dollars/ton, see details in Fig. 5.

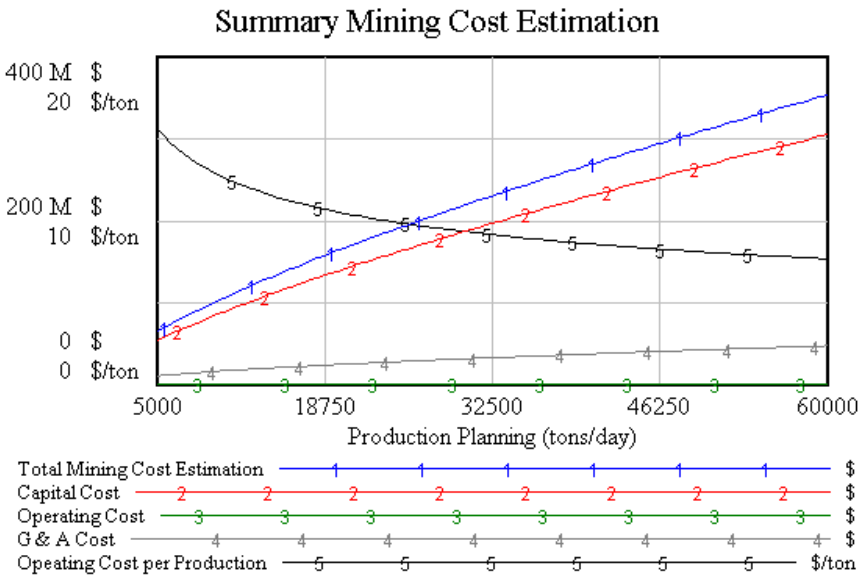

Figure 5: Summary Mining Cost Estimation

The example sensitivity analysis condition is shown in Fig. 6.

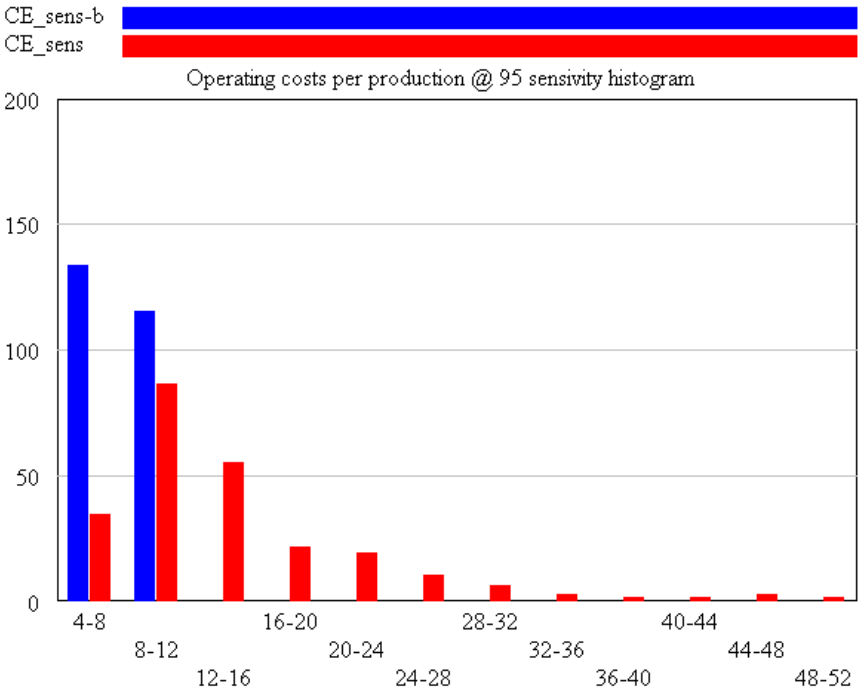

Figure 6: Sensitivity Analysis of Operating Cost per Production in 2 cases condition

The sensitivity condition result shows the probability of the target result value, in this example case focusing on production planning 57,250 tons/day (around 17 million tons/year). The operating cost per production, in the CE_sens-b sensitivity condition had a range between 4-12 dollars/ton (the highest probability range of result is 4-8 dollars/ton). The CE_sens sensitivity condition had a range between 4-52 dollars/ton (the highest probability range of result is 8-12 dollars/ton) (Fig.6).

6. Conclusion and Discussion

The System Dynamics Model of Mining Cost Estimation (DMMCE) can help to calculate the overall cost of mining rapidly. It's an alternative tool that flexible to change multiple values of input variables for creating many scenarios. It will be further developed for supporting decision making on mine investment and planning. In the example scenario condition, when mining production planning around 17 million tons/year, the total mining cost estimation is around 342 million dollars and operating cost around 7.8 dollars/ton.

Moreover, the sensitivity analysis conditions show probability result of operating cost per production when changing the stripping ratio and add function of environmental protection cost. It is equal 4-12 dollars/ton in the CE_sens-b condition, and equal 4-52 dollars/ton in the CE_sens condition.

For the further development, the DMMCE will verify with more case studies and include more detail of environmental protection cost variables, etc. After that, The System Dynamics Model of Mining Cost Estimation will be added to be a sub-system of the development of decision support system tool on the coal mining planning system in the future.

References

1. Hustrulid, W.A. and M. Kuchta, *Open pit mining planning & design*. 1998, Rotterdam ; Brookfield, VT: A.A. Balkema. 2 v. (xv, 836 p.).
2. Wikipedia.org. *System dynamics*. 2011 14 February 2011 [cited 2011 15 February]; Available from: http://en.wikipedia.org/wiki/System_dynamics.
3. Ventana System, I. *Vensim Software*. 2011 24 May 2011 [cited 2011 28 May]; Available from: http://www.vensim.com/software.html.
4. Darling, P. and Society for Mining Metallurgy and Exploration (U.S.), SME mining engineering handbook. 3rd ed. 2011, Englewood, Colo.: Society for Mining, Metallurgy, and Exploration. 2 v. (xxiv, 1840, I-46 p.).